No. VI.

Experiments on Air expoſed to Heat in metallic Tubes. By Dr. JOSEPH PRIESTLEY.

Read Aug. 15. 1800. HAVING lately ſent to the ſociety an account of ſome pretty remarkable experiments upon air heated in *earthen tubes*, I now take the liberty to communicate the reſult of ſome that I have made on air heated in *metallic tubes*. They are not leſs remarkable than the others; and being unable to explain ſeveral of them on any known theory, I ſhall be glad of the aſſiſtance of the members of the ſociety in the inveſtigations to which they may lead.

1. *Of a mixture of dephlogiſticated and inflammable air not exploding in a red heat.*

One remarkable circumſtance attending the heating of air in earthen tubes, and alſo in thoſe of metal, is that no mixture of dephlogiſticated and inflammable air will explode in them, though it always does in tubes of glaſs in which there is no metallic ingredient. With reſpect to earthen tubes, the fact may perhaps be explained by the eaſy tranſmiſſion of air through the heated tube, and even before the tube is red hot. The air in the inſide changing places with that on the outſide. In metallic tubes, this is not always the caſe, and when it is, it takes place much more ſlowly; ſo that an exploſion might be expected notwithſtanding this property.

Since, however, this mixture of dephlogiſticated and inflammable air will not explode in tubes of flint glaſs, in which there is the calx of lead, and they become black in this proceſs, as they do when inflammable air only is heated in them, this air muſt be ſeparated from the dephlogiſticated, and unite with the calx of lead. It is therefore

therefore probable that this takes place in the metallic tubes, though the metal is not in the ſtate of a calx, but may be, as it were, ſuper-ſaturated with phlogiſton. When I opened one of the copper tubes in which this experiment had been made, I found the metal exceedingly bright; whereas had any phlogiſton been ſeparated from it, it would have been covered with ſcale, being reduced to the ſtate of calx. Whether the ſame metallic tube would continue to have the ſame effect in this proceſs, or whether, when ſaturated to a maximum with phlogiſton, the mixture of air would have exploded in it, I did not try; ſeveral of the copper tubes, or the ſoder, having melted before this could be aſcertained.

I alſo found that when I threw the focus of a burning lens upon ſome clean filings of copper in inflammable air, much of the air diſappeared; having, no doubt, been imbibed by the metal, which muſt thereby have acquired more phlogiſton than naturally belonged to it.

For the purpoſe of theſe experiments I prepared a mixture of one-third dephlogiſticated and two-thirds inflammable air, each very pure, ſuch as made the loudeſt exploſions when a lighted candle was preſented to any portion of it; but neither in tubes of iron, copper, ſilver, or gold, was there any exploſion at all, though as ſtrong a heat as they would bear without melting was continued ever ſo long. As the quantity and ſtate of the air after the experiments deſerve ſome attention, I ſhall recite ſome of them.

One meaſure of the mixture above mentioned heated in a copper tube was reduced to 0.45, and was wholly phlogiſticated. Another meaſure of the ſame mixture expoſed to heat ten minutes in a tube of ſilver was reduced to 0.73, and then exploded. Another meaſure expoſed in a tube of gold was diminiſhed about one-third, and made a ſlight exploſion afterwards.

2. *Of the tranſmiſſion of air through the ſubſtance of ſome metallic tubes.*

When I had diſcovered the ready paſſage of air through bladders and earthen tubes, I thought the fact a very extraordinary one, and ſtill more, that the internal and external air ſhould change places, as I obſerved in my laſt communication to the ſociety. But I have ſince that obſerved that even ſome metallic tubes, though perfectly air-tight, admit the tranſmiſſion of air through them when they are heated. Of this I had no ſuſpicion till after heating air in the experiments above mentioned, I ſometimes let them remain a conſiderable time before I examined the air they contained; not doubting but that whenever it ſhould be convenient for me to do this, I ſhould always find the air in the ſame quantity, and of the ſame quality. But I frequently found that it was much increaſed, and that in theſe caſes there was always a conſiderable proportion of atmoſpherical air in them. This, however, was never the caſe with iron tubes, but with thoſe of copper, ſilver, and gold. As the firſt copper tubes I made uſe of were made of ſheet copper ſodered, I had one caſt ſolid; and though I found it to be perfectly air-tight, (as appeared by ſetting a ſyringe to it, and being unable by that means to force any air through it) it was evident that it was ſufficiently porous for the tranſmiſſion of air.

Having put $4\frac{1}{2}$ ounce meaſures of inflammable air into this copper tube, ſodered to a piece of a gun barrel, the end of which was immerſed in a baſon of mercury, I found that two ounce meaſures were expelled by the heat when the cloſed end was ſurrounded with hot coals. After continuing ſome time in this ſituation, I found in it 1.45 ounce meaſures, partially phlogiſticated, ſo that 25 meaſures were reduced to 1.45. Afterwards, though the tube continued perfectly air-tight, after a repetition of the ſame

ſame proceſs, there were found in the tube 3.5 ounce meaſures, which though it extinguiſhed a candle, was of the ſtandard of 1.7; ſo that ſome atmoſpherical air muſt have got into it.

One ounce meaſure of inflammable air expoſed to heat ſeveral hours in a *ſilver* tube, and left to cool gradually, came out two ounce meaſures, of the ſtandard of 1.42. The ſame quantity of the ſame air, after continuing only one hour in the heat, and examined immediately after it was taken from the fire; was only 0.72, and wholly phlogiſticated. At another time I kept the ſame quantity of the air three or four hours in the ſame heated tube, and being examined immediately it was only 0.21 wholly phlogiſticated, ſo that the tranſmiſſion of air did not take place while it was hot, but while the tube was cooling, which I thought very extraordinary.

The tube of gold was melted by inadvertently heating it too much before I had made many experiments with it; and ſeeing reaſon to conclude that its effect on the air confined and heated in it was no other than that of thoſe of ſilver, or copper, I did not renew it. I found, however, that a meaſure of inflammable air heated one hour in this tube was ſomething more than a meaſure, and then extinguiſhed a candle. There muſt, therefore, have been an addition to the air within from that without, though I neglected to examine it by the teſt of nitrous air.

It was not neceſſary to expoſe theſe tubes, and the air confined in them, to a red heat, in order to have this effect; for I had a ſimilar reſult when I only placed them near the fire in a degree of heat little greater than that of boiling water.

Air contained in clear water, is, as I have obſerved, ſomething purer than that of the atmoſphere; but when I filled a copper tube with water, and kept it a whole day in the circumſtance above mentioned, the air within

within it was of the ſtandard of 1.4. This, however, might have been tranſmitted through the water, as in ſome former experiments; but to prevent this I placed the open end of the tube (which was a piece of a gun barrel) in a baſon of mercury. Still, however, I found after ſome time the air was conſiderably increaſed in quantity, and almoſt as pure as the air of the atmoſphere. This, therefore, muſt have come through the pores of the veſſel, which, however, when it was examined in every method that I could think of, appeared to be perfectly air-tight.

Experiments relating to Phlogiſticated Air.

There is a peculiar difficulty reſpecting the conſtitution of phlogiſticated air; ſince ſome of my experiments ſeem to ſhew that it contains the principle of acidity, and others that it is intirely free from it; ſo that excepting its baſe (which is like that of all other kinds of air, viz. water) it conſiſts of nothing but ſome modification of phlogiſton.

When dephlogiſticated air is decompoſed together with much inflammable air, phlogiſticated air is produced; and in this caſe there does not appear to be any thing beſides this phlogiſticated air into which the oxygen of the dephlogiſticated air can enter. That the water which is found after this experiment does not contain any oxygen, I think I have ſufficiently demonſtrated; ſince it is not contained in finery cinder, where the new theory lodges it.

Alſo when ruſted iron becomes black by long expoſure to inflammable air, and is thereby converted into phlogiſticated air, the oxygen in the ruſt cannot be found except in this phlogiſticated air.

Notwithſtanding

Notwithſtanding this, in ſeveral other experiments inflammable air becomes phlogiſticated air without any addition of oxygen; as when it is expoſed to heat in copper or ſilver tubes, and probably, therefore, thoſe of other kinds of metal. Inflammable air treated in this manner is generally diminiſhed in quantity, though not always in the ſame proportion.

Three ounce meaſures of inflammable air expoſed half a day to a red heat in a copper tube were reduced to 0.52, completely phlogiſticated. Two ounce meaſures expoſed to the ſame degree of heat only a few hours, came out 1.25. Another equal quantity was reduced to three-fourths of an ounce meaſure; and two ounce meaſures expoſed in this manner twenty minutes came out 1.5, completely phlogiſticated.

I have, however, found a remarkable difference in the reſult of theſe experiments made with two caſt copper tubes, in one of which the metal is much thicker than the other. In the larger and thicker of theſe tubes, the air was always diminiſhed; and though it continually approached to the ſtate of phlogiſticated air, it was very ſlowly; whereas in the thinner tube the inflammable air was always increaſed in quantity, though the whole of it never failed to be phlogiſticated. In this tube phlogiſticated air alſo was always increaſed in quantity; whereas in the larger tube it was neither increaſed nor diminiſhed by the ſame treatment.

When I filled the ſmaller tube with water only, and expoſed the cloſed end to a red heat, I always found much more phlogiſticated air in it than when I uſed the larger tube in the ſame manner. Having filled the ſmaller tube with water, and only kept it in an inclined poſition over the fire, ſo that the heat to which it was expoſed did not much exceed that of boiling water, I found in it the next morning 4 ounce meaſures completely phlogiſticated.

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In order to vary the circumſtances of this experiment, I heated clean filings of copper, and alſo bits of ſilver, in inflammable air, by means of a burning lens; and the reſult was ſimilar, viz. a converſion of the inflammable into phlogiſticated air, for not only was the quantity of air diminiſhed, but the remainder was much leſs inflammable than before. After heating filings of copper in 14 ounce meaſures of inflammable air, till it was reduced to 7 ounce meaſures, I fired a quantity of it together with a quantity of dephlogiſticated air, when the diminution was to 0.77; though when the ſame dephlogiſticated air was exploded together with the ſame quantity of the original inflammable air the diminution was to 0.62. The ſame proceſs being repeated with the remainder of the inflammable air till it was reduced to $3\frac{1}{2}$ ounce meaſures, the diminution, when fired with the ſame quantity of dephlogiſticated air, was only to 1.25. When ſmall bits of ſilver were heated in the ſame manner in inflammable air, the reſult was the ſame, viz. a diminution both of its quantity and its inflammability.

In the following experiments phlogiſticated air was produced from atmoſpherical, dephlogiſticated, and nitrous, air.

Three ounce meaſures of atmoſpherical air expoſed a whole day to a red heat in a copper tube were reduced to $2\frac{1}{2}$, completely phlogiſticated; which is in the proportion of 91.6 of phlogiſticated air in 100. Conſequently, there muſt have been a production of phlogiſticated air in the proceſs.

Two ounce meaſures of dephlogiſticated air, of the ſtandard of 0.64, heated three or four hours in a caſt copper tube were reduced to ſomething leſs than 2 ounce meaſures, wholly phlogiſticated. And 4 ounce meaſures of the ſame dephlogiſticated air were in half a day

a day reduced to 1.25. In another tube, two ounce meaſures were in the ſame time reduced to 0.45, both completely phlogiſticated.

Four ounce meaſures of nitrous air were reduced in this proceſs to two completely phlogiſticated; whereas, in any other proceſs, only one-fourth of phlogiſticated air can be found in any given quantity of nitrous air.

Air naturally contained in clear water is ſomething purer than common air; but air produced by expoſing metallic tubes filled with water to a moderate heat, ſo as to be kept ſome time in the ſtate of *ſteam*, is always leſs pure than atmoſpherical air. There muſt, therefore, be a production of phlogiſticated air in this caſe alſo.

Having filled a *ſilver* tube with water, and kept it ſuſpended over the fire a whole day, I found the air within it of the ſtandard of 1.25, when the air expelled from the ſame water was of the ſtandard of 1.0. Uſing a tube of *lead*, in the ſame manner, the air within it was of the ſtandard of 1.6. In both theſe caſes, therefore, there muſt have been a production of phlogiſticated air, and probably from the phlogiſton of the metals.

P. S. Since I wrote the preceding account I have found that inflammable air heated in a gun barrel is ſo far from approaching to the ſtate of phlogiſticated air, that, when it is fired together with dephlogiſticated air, the diminution is greater than with the original inflammable air. This I tried twice, keeping the gun barrel in a red heat the whole day, and not examining the air till the next morning. This difference between the effect of copper or ſilver, and of iron, on inflammable air, in the ſame degree of heat, is not a little remarkable.

To the account of theſe experiments I ſhall add, that pure phlogiſticated air may be procured in the eaſieſt

and ſureſt manner, by means of iron only, without any mixture of ſulphur. To do this I fill phials with turnings of malleable iron, and having then filled them with water, pour it out, to admit the air of the atmoſphere, and in ſix or ſeven hours it will be diminiſhed in the ſame proportion as by iron filings and ſulphur; and the ſame iron will anſwer this purpoſe I do not know how long, but it will be till all the iron is converted into ruſt. What remains of air in the phial will be the pureſt phlogiſticated air. Iron that is quite dry has no ſuch effect on air.

The *readieſt* method of procuring phlogiſticated air is, no doubt, by means of a mixture of nitrous air with that of the atmoſphere: but it is liable to ſeveral objections; eſpecially that from not knowing the exact quantity of nitrous air to be employed for this purpoſe, on account of the different ſtates of each of thoſe kinds of air; though I have not found that of the atmoſphere to be ſenſibly different, except in circumſtances of which every experimenter is ſufficiently apprized.

Many of the moſt important experiments recited in theſe papers were made with a burning lens of ſixteen inches diameter, with which I was generouſly furniſhed by Mr. Parker, who has ſo much diſtinguiſhed himſelf by his improvements in the art of grinding glaſs. To his liberality in ſupplying me with various veſſels made of glaſs, the public is indebted for a great proportion of my other experiments on air.